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AUTHOR Smith, Brandon B.
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ABSTRACT

Research was undertaken to determine if the free association methodology was a reliable and valid technique to map hierarchical associative technical knowledge. A sample consisting of four flexible and four inflexible workers in the radio/television repair and the mobile radio repair occupations responded to 163 radio and television words and 184 words for mobile radio communications, respectively. The free association responses for the four flexible and the four inflexible workers in each of the two occupations were pooled and subsequently subjected to a hierarchical factor analysis procedure. The associative methodology produced technical conceptual maps with face and content validity for flexible and inflexible workers in each occupation. Flexible workers had a larger and different technical vocabulary, and there were visual differences in the number and structures for the flexible workers and inflexible workers. Results suggested that the free association procedure is quite reliable and capable of producing technical associative structures for a technical field showing differences between groups of workers at different levels of proficiency and capable of producing a conceptual map of technical content that may be useful in curriculum development. (The instrument and some figures are appended.) (YLB)

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# COGNITIVE STRUCTURE OF TECHNICAL KNOWLEDGE:

# A FREE ASSOCIATION METHODOLOGY

Brandon B. Smith
Minnesota Research and Development Center
for Vocational Education
University of Minnesota
St. Paul, Minnesota

American Educational Research Association
Montreal, Canada

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# COGNITIVE STRUCTURE OF TECHNICAL KNOWLEDGE: A FREE ASSOCIATION TECHNIQUE

Brandon B. Smith
Minnesota Research and Development Center
University of Minnesota
St. Paul, Minnesota

## Introduction

Cognitive psychologists Ausubel (1963, 1964), Bruner (1960, 1966), and verbal learning (Deese, 1962, 1964), and curriculum and instructional theorists Schwab (1964), (Lang, 1964), (Scriven, 1964), (Phenix, 1964), Bellack, 1964, (Briggs 1967) all have expressed a concern for the importance of the structure of knowledge as an important variable in studing the issue of instructional effectiveness. While some theorists have postulated and developed a theoritical structure of knowledge for various disciplines/fields like the arts (Brody, 1964) or mathematics (Lang, 1964) or social sciences (Scriven 1964) there has been no empirical procdure by which the structure of knowledge can be identified in the technical/vocational fields. The structure in these fields is based primarily on task analysis (Gagne', 1964, Christal, 1970), (Fryklund, 1943), which often yields simply lists of tasks presented to learners from simple to complex tasks where simple tasks are believed to be prerequisite to more complex tasks (Gagne', 1965) rather than as parts within a more inclusive structure of knowledge (Shoemacher, 1967). Ausubel, (1963, 1964) further warns that the logical structure of knowledge (e.g. task analysis) is quite different from the psychological structure of knowledge which Learner's derive as the result of interacting with content presented in a "logical" manner.

With these thoughts in mind research was undertaken to determine if the free association methodology was a reliable and valid technique to "map" the hierarchical associative, technical, structure of knowledge of workers in the

television repair and radio communications repair occupations.

The objectives of the study were to determine (1) whether the technique was reliable for flexible and inflexible workers in the two occupations (2) whether there were differences in the size and quality of the technical vocabulary of flexible and inflexible workers in the two occupations (3) whether there were differences in the flexible and inflexible workers in terms of the number of factors and organization of the hierarchical associative structure of factors and (4) whether there were qualitative differences between flexible and inflexible workers in the two occupations as reflected in the (1) verbal labels of the structure, and (2) the technical accuracy of the structure of labels and factors in the judgement of a group of five electronic teacher/experts.

Rationale for the study

The rationale for the studies suggests that if in fact the free association methodology is sufficiently sensitive to the qualatative differences between flexible and inflexible workers in the two occupations, then the methodology might also be used in other fields (military) Ammerman (1970) and with other student populations (Liu, 1972 & Nee, 1977) and for the purpose of instructional evaluation (Currey, 1983).

Further, the rationale suggests that a small purposive sample of the "best" performing/knowledgable workers in the specific occupation can be identified then it would be possible to develop curriculum and instructional methods based on the structure for other learner groups in the respective occupations.

Sample

Two groups of four flexible and four inflexible workers in the radio/TV repair occupation and the mobile radio repair occupation respectively were selected from nine different firms each of which employed at least ten

individuals for the same payroll job. The immediate supervisor in each firm rank ordered all workers in these payroll positions according to four criteria:

(1) Workers who could perform the greatest and fewest variety of repair jobs

(2) Workers who could repair the most novel complex jobs

(3) Workers who brought the fewest number of repair jobs back to the shop for repairs

(4) Workers who could repair/align the greatest number of different makes/models or brands of receivers or transmitters.

Rationale and assumptions of the methodology

The rationale used for this series of studies was based on the work of Deese (1962, 1964), Bertram Garshof and John Houston (1963), Paul Johnson (1964, 1967); David Ausubel, (1963, 1964), and Jerome Bruner (1962, 1966). All of these individuals are interested in the structure of knowledge and verbal learning. Their work with the concepts of verbal learning and/or the free association technique has made it possible to make the following assumptions about the technique with a reasonable degree of assurance.

1. Technical fields or occupations have a body of technical knowledge which is believed to be related to the quality of performance of workers in the field.
2. The technical knowledge of a field possessed by an individual consists of concepts which are the psychological meaning of the tools, processes, and other verbal elements of the field.
3. Individuals organize their technical concepts into an integrated structure dependent upon the functional relationship to other concepts in the occupational area.
4. Technical terms or words are verbal labels for concepts.

5. Experienced workers who are performing in the technical field passes the verbal labels necessary to assess their meanings of various technical concepts.
6. The associative meanings of a concept is defined as the total free association response distribution which a given stimulus word elicits.
7. The first response to a stimulus word is more highly related to the psychological meaning of a stimulus word than later responses.
8. The total stimulus word domain can be identified by repeated administrations of a free association instrument to a group of individuals until no new technical words are elicited as responses.
9. The associative relatedness (meaning) of two concepts is determined by the extent of overlap between the two associative response distributions (meanings) for an individual or group of individuals.
10. The associative structure of technical concepts can be generated for an individual or group of individuals by calculating a matrix of relatedness coefficients (RC between all possible pairs of associative meaning to stimulus words).
11. The graphic pictorial structure of technical concepts can be identified by subjecting the relatedness (RC) matrix to some type of mulidimensional solution, to generate a hierarchical structure of associative meaning of factors which can meaningfully be labeled (face/content validity) of the hierarchical structure.

In summary, it is believed that it is possible to empirically identify the technical conceptual structure for any field or occupation by identifying an individual or group of individuals who are performing the work in a manner we wish students to emulate. Once the conceptual structure is produced it is

possible to (a) present it in terms of either group or individualized instruction, (b) organized from whole to part instruction, and (c) relate psychomotor skills to the cognitive structure at appropriate, relevant points in the curriculum. (Shoemacher, 1967) in accordance with the principle of "chunking" discussed by Miller (1956).

Stimulus Word/Administration

A total of about 450 technical electronic terms were identified from technical manuals and groups of experts for the two appliance repair fields. A random sample of 163 radio and television words and 184 words for mobile radio communications were selected respectively.

The stimulus words were randomly arranged into four different free association test booklets in order to control for possible chaining effect and were administered to the flexible and inflexible workers in two, two-hour test sessions on successive days in each of the two occupations. Each page of the booklet provided a different stimulus word at the top of each page and sufficient space to write twenty-five responses to each stimulus word. Each worker was given only one minute to respond to a stimulus word with as many technically related terms as possible. A tape recorder with a signal tone replicated at one minute intervals was used to control response time. Twenty words were randomly selected and randomly placed in each of the two test booklets to assess the stability of the free response techniques.

Pooling Responses

The free association responses for the four flexible and the four inflexible workers in each of the two occupations were "pooled" respectively. The pooling process eliminated idiosyncratic responses and resulted in a relatively unbiased, salient, agreed upon, rank ordered associative meaning for each stimu-

lus word elicited from a purposive sample of four flexible and inflexible workers in each of the two appliance repair fields.

A majority of the calculations in the two studies used the relatedness coefficient (Garshof and Houston (1963)). The RC is a measure of the extent to which two response distributions overlap or the extent to which the associative meaning of two words are similar or different. The magnitude of the RC is inversely proportional to the psychological distance between two concepts. The RC ranges from .00 to 1.00 where .00 indicates no relationship between two associative concepts and a 1.00 means the associative meaning of the concepts are identical.

RC coefficients were calculated between the pooled associative meaning of the twenty randomly selected test-retest stimulus words to assess the reliability of the procedure.

The RC statistic was also used to compute the relationship among all possible pairs of the 163 and 184 stimulus word matrics for the radio television and radio communications occupations respectively, thus producing a first order associative structure matrix for the flexible and inflexible workers in each of the two occupations. The 163 and 184 associative structure matrix was then factor analyzed using the principle component analysis with a varimax rotation. Operationally the factors were statistically defined by those stimulus words which loaded .300 or higher on a factor.

The associative meaning for each factor was then redefined by pooling all of the original responses for each stimulus word which loaded .300 or higher on the factor. A new second order associative structure matrix was generated and then subsequently factor analyzed. The procedure was repeated until it was no longer possible to reduce the factor structure. Associative (pictorial) maps were

drawn showing the relationship of lower order to higher order factors. Electronic experts in the field were than asked to provide labels for each lower order and higher order concept by (a) looking at the response distribution to each factor, (b) looking at the relationship among factors and (c) providing an appropriate table to each factor.

Findings

1. The pooled associative meaning for flexible and inflexible workers in the two occupations were reliable. The median RC coefficient for the twenty randomly selectd test-retest stimulus words was .80.
2. The associative methodology produced technical conceptual maps with face and content validity for flexible and inflexible workers in each of the two occupations as judged by eletronic experts.
3. The technical, conceptual structures (maps) for flexible and inflexible workers for each of the two occupations were different in several highly meaningful ways.
   a. Flexible workers had a larger and different technical vocabulary as measured by (1) the size of the pooled response distribution, (2) the number of different technical terms used and (3) their meanings to 24 and 33 percents of the initial list of stimulus words in the radio television and radio communication occupation respectively.
   b. There were visual differences in the number and organization of the structures for the flexible workers and inflexible workers. The flexible worker structures were more balanced, integraded and provided greater differentiation among concepts than did the structures for the inflexible workers. In both occupations there

were four hierarchical levels of most inclusive to less inclusive factor concepts for flexible workers as compared to inflexible workers. Also, the flexible workers had the largest number of integrated factors within their structure and the fewest number of "isolated" factors. While inflexible workers in the two occupations had a less well integrated factor structure the greatest number of a "isolated" factors. (e.g. factors which were not integrated in the hierarchical structure of associative meanings.)

In conclusion, the results of the two studies suggest that the free association procedure is quite reliable and capable of producing technical association structures for a technical field showing differences between groups of workers who are known to be performing their job at different levels of proficiency. In addition, the procedure is capable of producing a conceptual map of technical content which has face and content validity for experts in the field which may therefore be useful as a way in which to develop curriculum and teach technical content "whole to part" in either individualized or group instruction. This would provide learners with a visual picture of the relationship among technical concepts. The conceptual associative maps provide the learner with a graphic "picture" of the "whole" of the learning task while simultaneously showing them the psychological relationship of the various parts to the whole.

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Appendix A

DIRECTIONS

You will be given a key word and you are to write down as many other words which the key word brings to mind as you can. These other words which you write down may be things, places, ideas, events, or whatever you happen to think of when you see the key word.

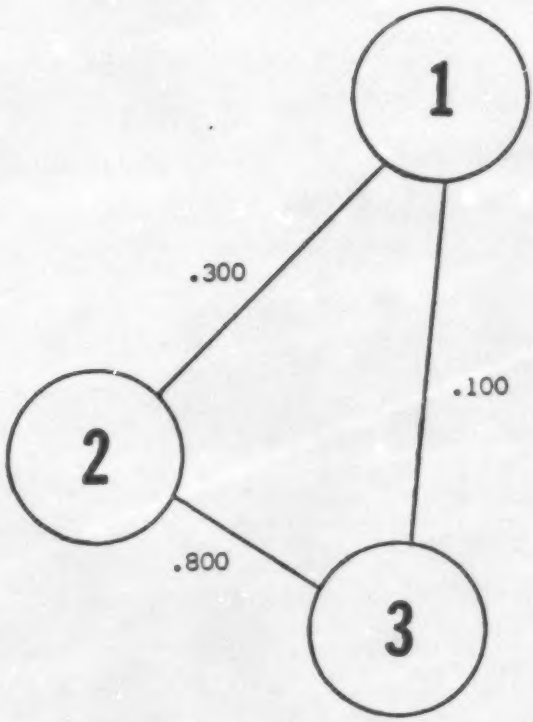
For example, think of the word, KING. Some of the words which KING might bring to mind are written below:

| | |
|---|---|
| King | Queen |
| King | Cole |
| King | Ruler |
| King | Sky |
| King | Kingdom |
| King | England |
| King | Imperial |
| King | Kingfish |

No one is expected to fill in all the spaces on a page, but write as many words as you can which the key word brings to mind. Be sure to think back to the key word after each word you write down because the test is to see how many other words the key word makes you think of. A good way to do this is to repeat the key word over and over as you write.

Appendix B

AN EXAMPLE OF CONCEPTUAL STRUCTURE: THE PSYCHOLOGICAL RELATIONSHIP AND DISTANCE AMONG A SET OF CONCEPTS



## Appendix C

### DEFINITION OF (RC) RELATEDNESS COEFFICIENT

The Relatedness Coefficient (RC) is defined as the amount of observed overlap to the maximum possible overlap between two rank order, free association response distributions.

$$RC = \frac{\bar{A} \cdot \bar{B}}{(A \cdot B) - 1}$$

The product (A • B) represents the intersect which would be obtained if every element in A appeared in B (and B in A) and in the same order. A and B are operationally defined by the product sum of the longest rank ordered response distribution of the two stimulus words. Where the two stimulus words are different, a minus one (-1) is used in the denominator to represent an unbiased estimate of maximum overlap. The product $\bar{A} \cdot \bar{B}$ is the product sum of the rank orders of response commonalities observed between two response distributions.

Example

COMPUTATION OF A SAMPLE RC FOR THE STIMULUS WORD YOKE AND DEFLECTION

| Associates to "Yoke" | Frequency | Rank | Associates to "Deflection" | Frequency | Rank |
|---|---|---|---|---|---|
| Yoke | 4 | 6 | Deflection | 4 | 6 |
| Deflection | 4 | 5 | Yoke | 3 | 5 |
| Horizontal | 3 | 4 | Horizontal | 2 | 4 |
| Vertical | 3 | 3 | Vertical | 2 | 3 |
| Ringing | 2 | 2 | Circuit | 2 | 2 |
| Trapezoidal | 2 | 1 | | | |

A = Rank order of responses to "Yoke". (6, 5, 4, 3, 2, 1)
B = Rank order of responses to "Deflection". (6, 5, 4, 3, 2, 1)
C = Common Responses. (Yoke, Deflection, Horizontal, Vertical)
$\bar{A}$ = (6, 5, 4, 3)
$\bar{B}$ = (5, 6, 4, 3)

$$RC = \frac{\bar{A} \cdot \bar{B}}{(A \cdot B) - 1} = \frac{(6, 5, 4, 3) \cdot (5, 6, 4, 3)}{(6, 5, 4, 3, 2, 1) \cdot (6, 5, 4, 3, 2, 1) - 1} = \frac{85}{(91 - 1)} = .904.$$

Appendix D

THE LABELED TECHNICAL CONCEPTUAL STRUCTURE OF STIMULUS CONCEPTS FOR A GROUP OF FLEXIBLE RADIO AND TELEVISION REPAIRMEN

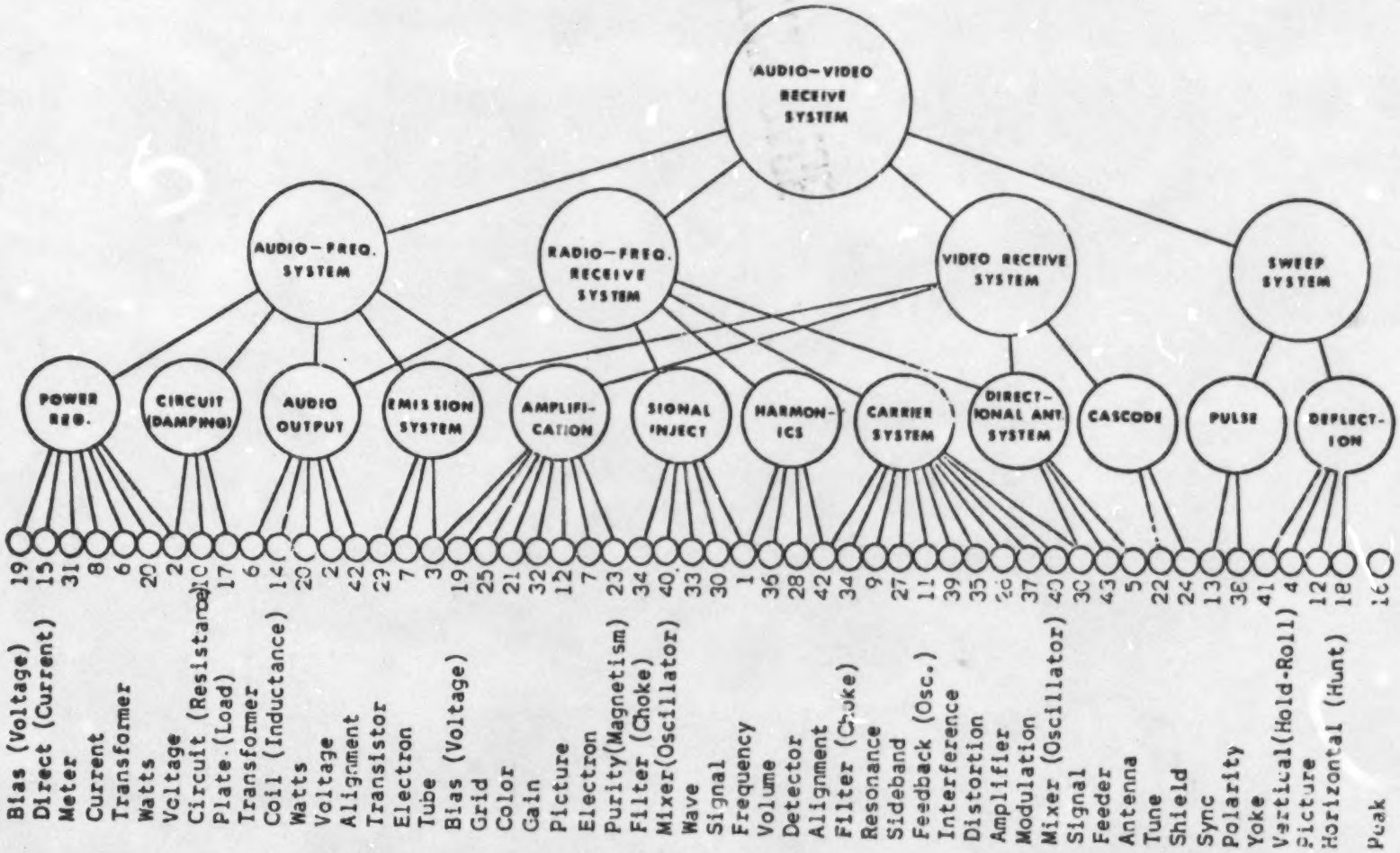
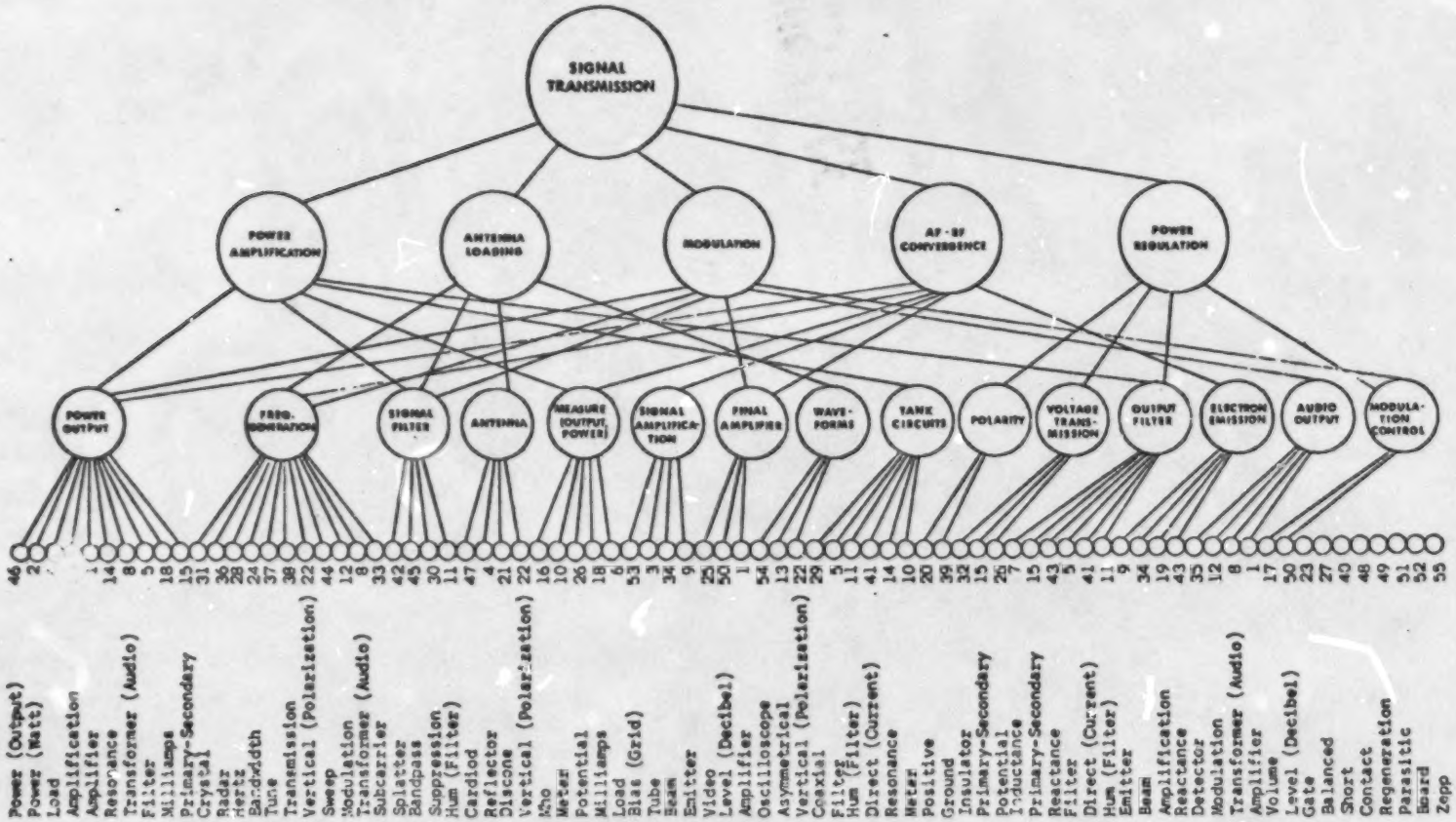


FIGURE IX

THE LABELED TECHNICAL CONCEPTUAL STRUCTURE OF STIMULUS CONCEPTS FOR A GROUP OF FLEXIBLE RADIO COMMUNICATIONS REPAIRMEN



Appendix F

THE LABELED TECHNICAL CONCEPTUAL STRUCTURE OF STIMULUS CONCEPTS FOR A GROUP OF INFLEXIBLE RADIO AND TELEVISION REPAIRMEN

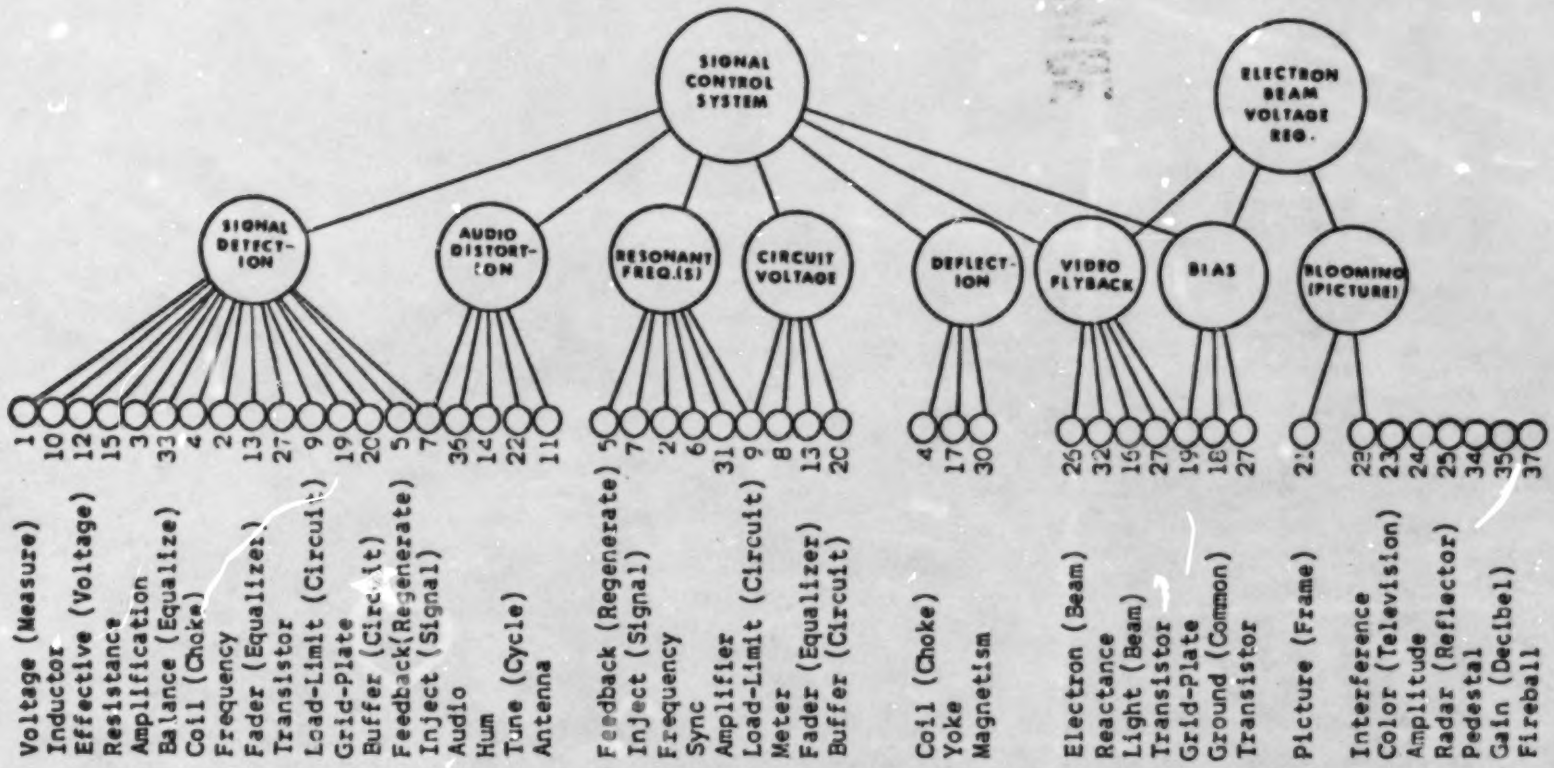
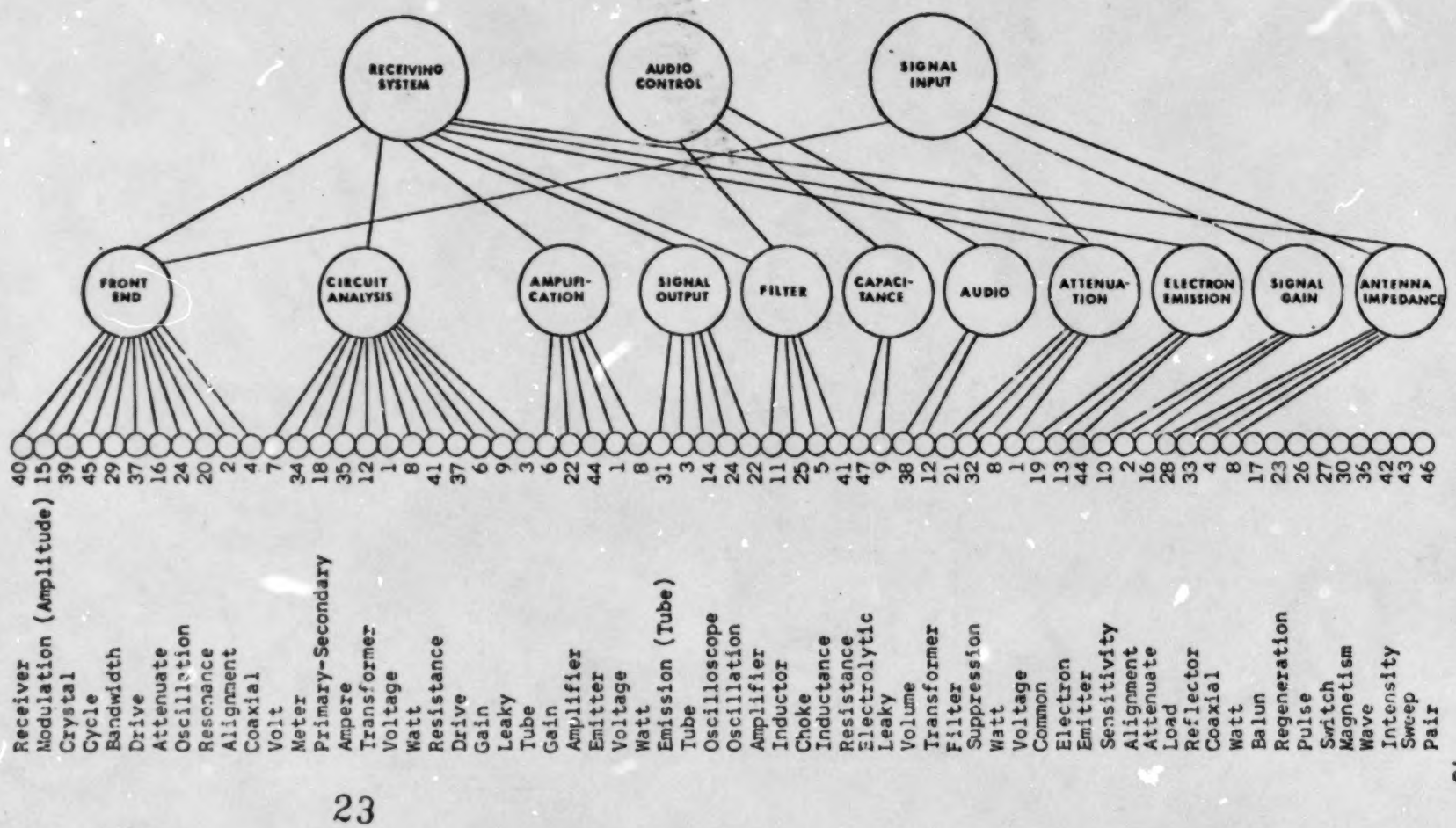


FIGURE X

THE LABELED TECHNICAL CONCEPTUAL STRUCTURE OF STIMULUS CONCEPTS FOR A GROUP OF INFLEXIBLE RADIO COMMUNICATIONS REPAIRMEN



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